70MHz 7W low power linear amplifier

A 7w linear amplifier using the Mitsubishi RA07H0608M RF MOSFET power amplifier module. This amplifier was designed for use with the Nacton70MHz transverter.

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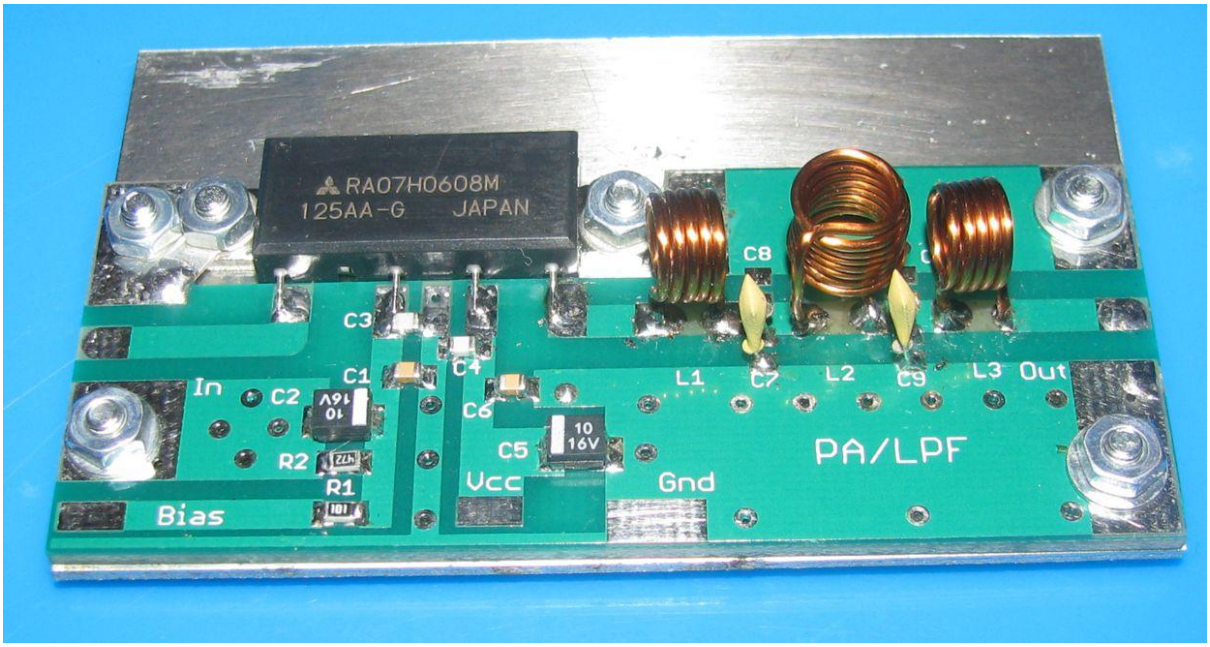


Introduction

Four Metre amateur band linear power amplifiers are relatively easy to design. However the ready availability of the low cost Mitsubishi RA07H0608M module makes it an attractive option for use with the Nacton and other low power transverter modules.

The two-stage Mitsubishi RA07H0608M module features very stable, low voltage (12V) operation, with high gain at low drive level. It also has good linearity, especially when the output is kept below about 4W PEP. The amplifier operates in Class AB.

The 7W power level is adequate for driving most modern 50 Volt powered RF MOSFET or valve linear amplifiers to full UK legal output power. The 7W amplifier incorporates a Low Pass Filter (LPF) to reduce harmonic output.

7W will be found enough power to work the majority of European stations during sporadic E openings.

The following article describes an amplifier that was designed for use with the 70MHz Nacton transverter. The same PA board can also be used with the 144MHz version of the Nacton, but with a suitable PA module and component values in the gate bias and LPF. The 144MHz amplifier version will be described in a separate document.

Power Module Module

The Mitsubishi RA07H0608M is a small (30 x 10 x 5.4 mm) power amplifier module using RF MOSFET technology. The device number indicates it is a 7W amplifier for use between 60 and 80MHz. The amplifier module draws less than 1.5A at 13.5V at full output.

It has four connection pins plus ground (Heat-sink tabs). These connections are, from left to right:-

1 RF Input (P_{in})	50mW max
2 Gate Voltage (V_{GG})	5V max
3 Drain Voltage (V_{DD})	13.2V max
4 RF Output (P_{out})	up to 10W saturated
& RF Ground (Case)	

According to the manufacturers RA07H0608M data sheet the drain voltage should not exceed 13.2V when running 5V gate bias. In practice I have used 13.5V with a full 5V gate bias with no failures to date. However, the gate bias voltage is purposely held just below 5V by R1 and R2. A series-connected 3 Amp silicon rectifier diode, D1, in the supply to the amplifier, is recommended in order to drop the supply voltage from the usual 13.5V and also to provide protection against accidently reversing the supply to the transverter and amplifier.

Circuit

This is very straightforward. The circuit schematic is shown in Fig 1

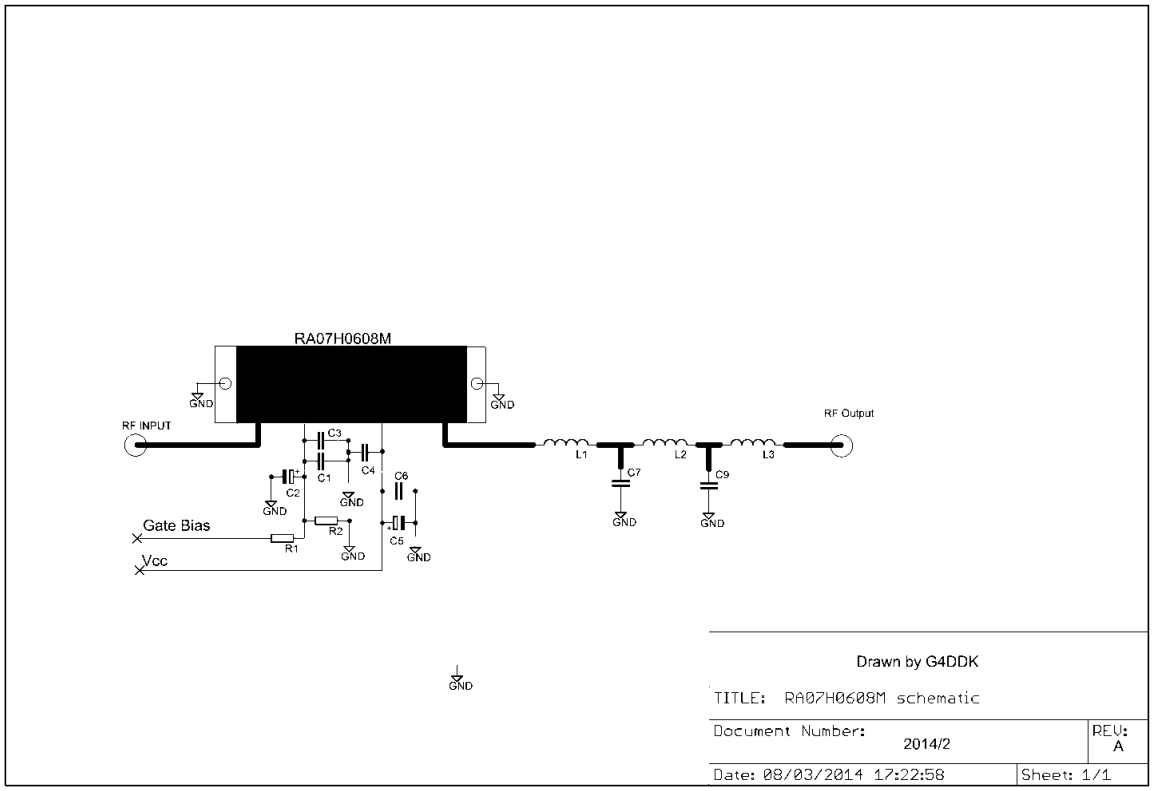


Table 1 shows the component values.

Designation	Value	Type
C1	10nF	0805 SMD
C2	10uF Tantalum 16V - 20V wkg	Case B SMD
C3	100pF	0805 SMD
C4	100pF	0805 SMD
C5	10uF Tantalum 16V - 20V wkg	Case B SMD
C6	10nF	0805 SMD
C7	47pF	Ceramic plate
C8	Not used	
C9	47pF	Ceramic plate
C10	Not used	
R1	100Ω	0805 SMD
R2	4.7kΩ	0805 SMD
L1	See table 2	
L2	See table 2	
L3	See table 2	
IC1	RA07H0608M	PA Module

Table 1 component values for the PA and low pass filter. The low pass filter coil details are shown in table 2

The component overlay is shown, over-size, in figure 2

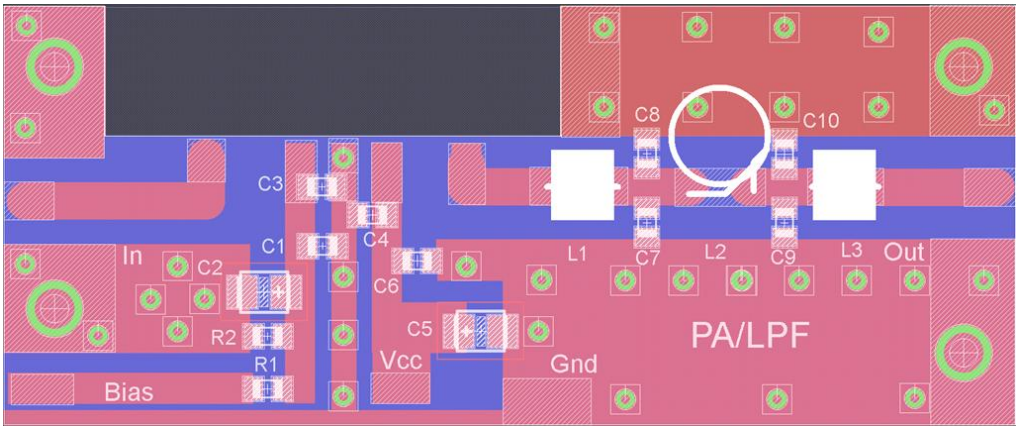


Fig2 Component overlay for the 70MHz amplifier module with LPF. C8 and C10 are not used in this version of the amplifier module.

Note that the PA/LPF PCBs supplied in kits may be slightly different to the one shown in Fig 2

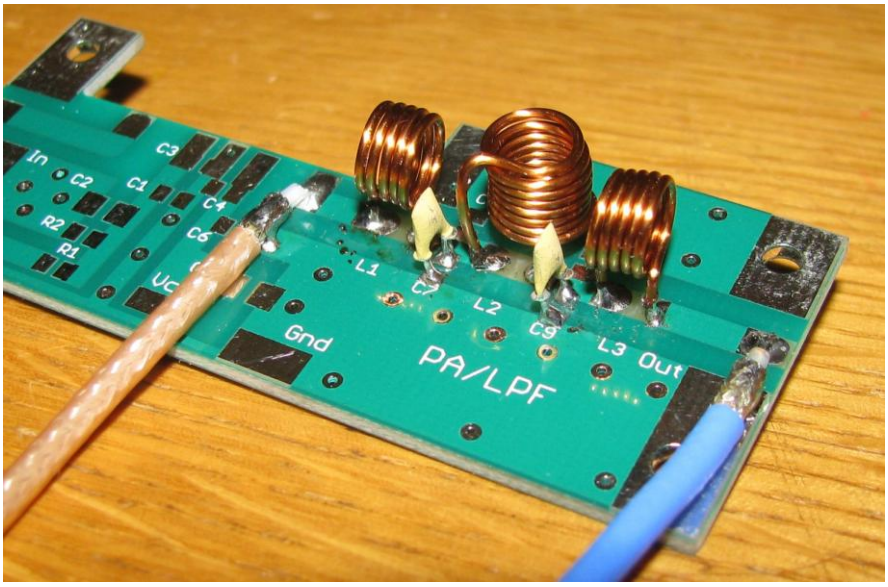
The layout consists of a number of decoupling capacitors connected to the supply and bias pins of the PA module, with two fixed gate bias setting resistors. The low pass filter ensures that the harmonic output from the PA module meets current UK out of band spurious output recommendations for amateur radio transmitting equipment.

LPF

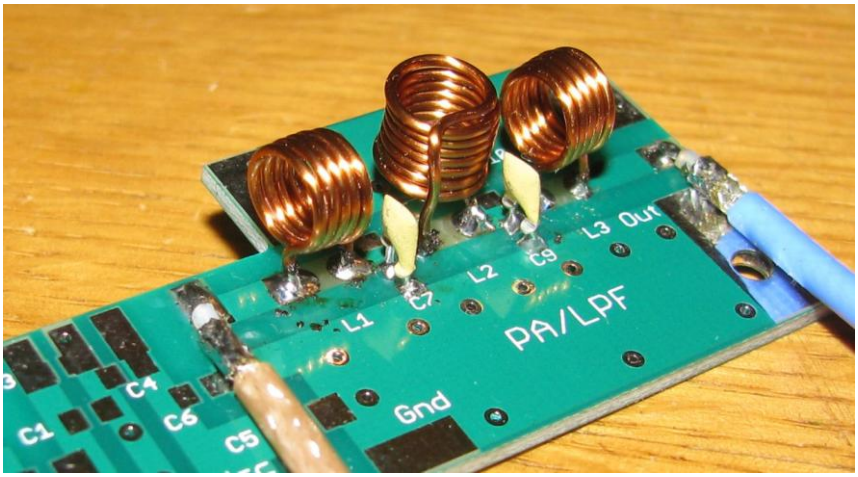
This is the most critical part of the module as it must exhibit low loss at 70MHz with good matching and yet reduce the harmonic output from the amplifier to acceptable levels. The low pass filter, consisting of L1, C7, L3, C9 and L3, (Note that C8 and C10 are not used in the 4m PA/LPF) has been carefully modelled and then tested to check that it agrees with the model design.

22SWG (0.7m) diameter enamel insulated wire is used to produce the required inductance values for L1, L3 and L3. Together with leaded capacitors these form the low pass filter. Provision is made on the board for C7 and C9 SMD capacitors but the leaded parts were found to work just as well and are easier to obtain. C8 and C10 are not used in the 4m LPF. L2 is mounted perpendicular to L1 and L3 to reduce unwanted coupling between these inductors.

The filter has 0.15dB insertion loss at 70MHz with over 20dB input return loss. The second harmonic, at 140MHz, is suppressed over 30dB and the third harmonic by over 50dB. Higher harmonics are suppressed over 60dB. Additional stages of filtering can be added if required, but at the expense of increased insertion loss.



Low Pass Filter view 1



LPF view 2. The LPF is shown with temporary coax connections to allow testing of the filter response independently of the power amplifier module. Note that L2 has one short connection and one long connection. L2 is offset from the connecting tracks.

Coil orientation details

Coil	Turns	Coil orientation
L1	5	Horizontal
L2	8.25	Vertical
L3	5	Horizontal

Table 2 Low pass filter coil details

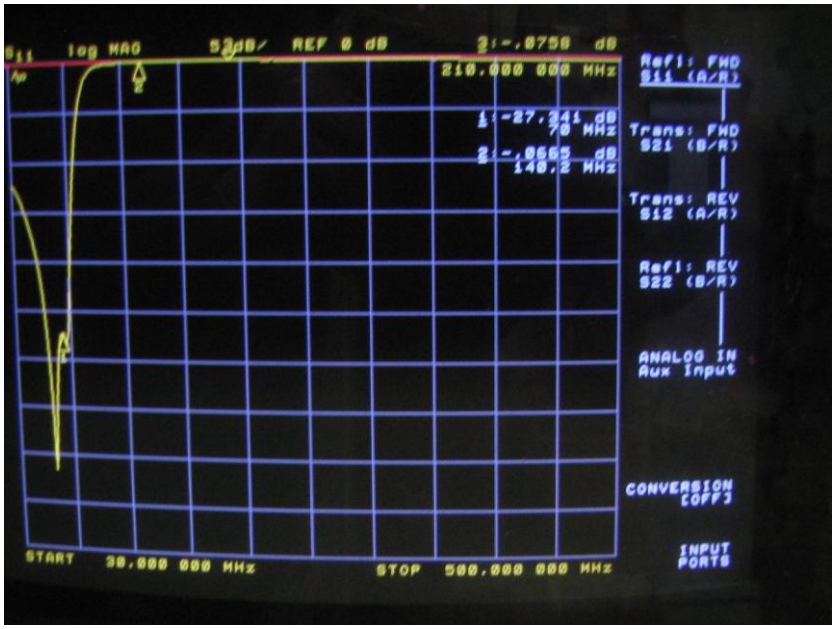
All coils use 22SWG (0.7mm) enamel covered copper wire, close wound on a 5.5mm diameter former such as a 5.5mm drill shank. Remove the former after the coil is wound!

At the end of the coils carefully bend the wire tails down from the coil as shown, cut to about 1.5mm long and then tinned with a VERY hot soldering iron to remove the insulation coating for approximately 1mm. L2 requires that the top tail is cut longer, as shown, so as to contact the same

pad as C7. It should not be necessary to 'tune' the coils if wound and mounted as shown in the two photos above.

Frequency response and return loss of the LPF

Frequency response of the 70MHz LPF. Vertical scale id 5dB/Division



Return loss (matching) of the LP. Again at 5dB/Division

Amplifier construction

The first thing to do, even before soldering any parts onto the PCB, is to cut a small, flat, sheet of thin aluminium, the same size as the PCB, but WITHOUT the cut out for the module. This is the heat spreader plate (HSP)that goes between the PCB and the case. The Mitsubishi module is also screwed to this plate. An ideal thickness is about 0.8 - 1mm.

Offer the PCB up to the HSP and mark the position of the four PCB mounting holes through, onto the HSP. Do not mark the holes for the module at this stage.

Drill four mounting holes in the HSP. I drilled 2.5mm holes.

Bolt the PCB to the HSP using short M2.5 nuts and bolts. Ensure the edges are square.

Offer the module up to the PCB ensuring that the four connecting leads line up with the four tracks on the PCB. as shown in the photo below. Carefully mark the positions of the two mounting holes for the module.

Remove the module and place safely on one side.

Unbolt the PCB from the HSP.

Drill the two mounting holes for the module by drilling through the HSP. Again, 2.5mm seems about right.

Bolt the PCB to the HSP.

Ensure the edges are square.

Offer up the module to the HSP and PCB. DO NOT SOLDER THE MODULE TO THE PCB at this stage!

Bolt the module temporarily to the HSP.

Check everything is square and that the module pins still line up.

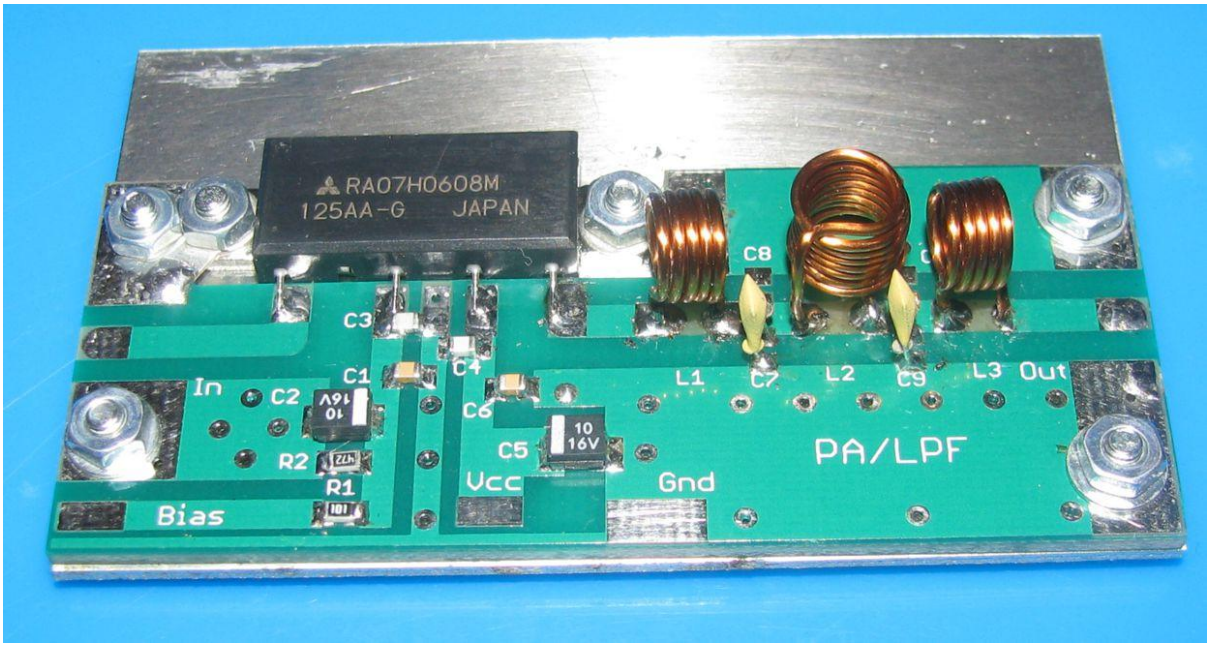
Before going any further it would be wise to mark where you need to drill mounting holes for the amplifier in the case. This is best done by marking the (Hammond) case from the outside, using the HSP as a template, making sure that you have drilled 6 holes; four for the HSP and two for the amplifier module.

Temporarily assemble the amplifier inside the case to check all the holes are in the right places.

Out of the case, again bolt the PCB to the HSP.

Spread a VERY THIN layer of heat sink compound on the bottom of the module.

Bolt the module to the HSP ensuring that the pins line up. You should use a longish solder tag on each of the two module mounting bolts as shown below. These tags should be soldered to the adjacent areas of tinned copper PCB to ensure a good, low inductance, grounding to the PCB. Do not use an excessive amount of heat sink compound on the bottom of the module a thin, consistent layer is adequate.



Note that the HSP shown above is slightly bigger than described.

If you want to test the 7W amplifier with the rest of the Nacton transverter then see the wiring information in the next section. Note that the amplifier 'Bias' is 5v and comes from the Nacton module. If you don't have a Nacton you will need to provide a suitable 5V bias externally. If the amplifier is tested without bolting into the case, a small fan can be used to blow cold air over the HSP.

Nacton transverter wiring

There are several ways to interconnect the transverter module with the PA/LPF depending on what you want to achieve. The method shown in figure 3 allows the Nacton transverter **+5v on transmit** output to provide the gate bias for the power amplifier module. The Vcc supply is left connected to the RA07H0608M whilst the transverter is switched on. The switched bias enables the PA for transmit.

The two 1N5401 silicon diodes provide reverse polarity protection if the supply is accidently reversed. Also, D1 drops the supply voltage from 13.5 to 12.8V for the RA07H0608M module, whilst D2 additionally drops the voltage another 0.7V for the Nacton transverter module, thus reducing the dissipation in the on-board voltage regulators. A third diode, D3, may be connected in series with D2, to the transverter module VCC input to further reduce the transverter module supply, if felt necessary.

It is HIGHLY RECOMMENDED that a 6dB attenuator be used between the Nacton transverter module and the PA/LPF as the output from the transverter module is quite capable of overdriving and destroying the PA/LPF if too much IF drive is applied. A suitable Pi attenuator can be made with two shunt 150Ω 0805 size resistors and one series 39Ω 0805 size resistor. These can be mounted on the PA/LPF PCB by cutting the PA/LPF PCB input track and inserting the 39Ω resistor across the cut and the 150Ω resistors to the ground plane at either end of the 39Ω resistor.

The Nacton's **+12v tx out** can be used to operate a suitable 12v coaxial relay for transmit/receive antenna changeover whilst the **EOT** (Earth On Transmit) can be used to enable an external high power linear amplifier.

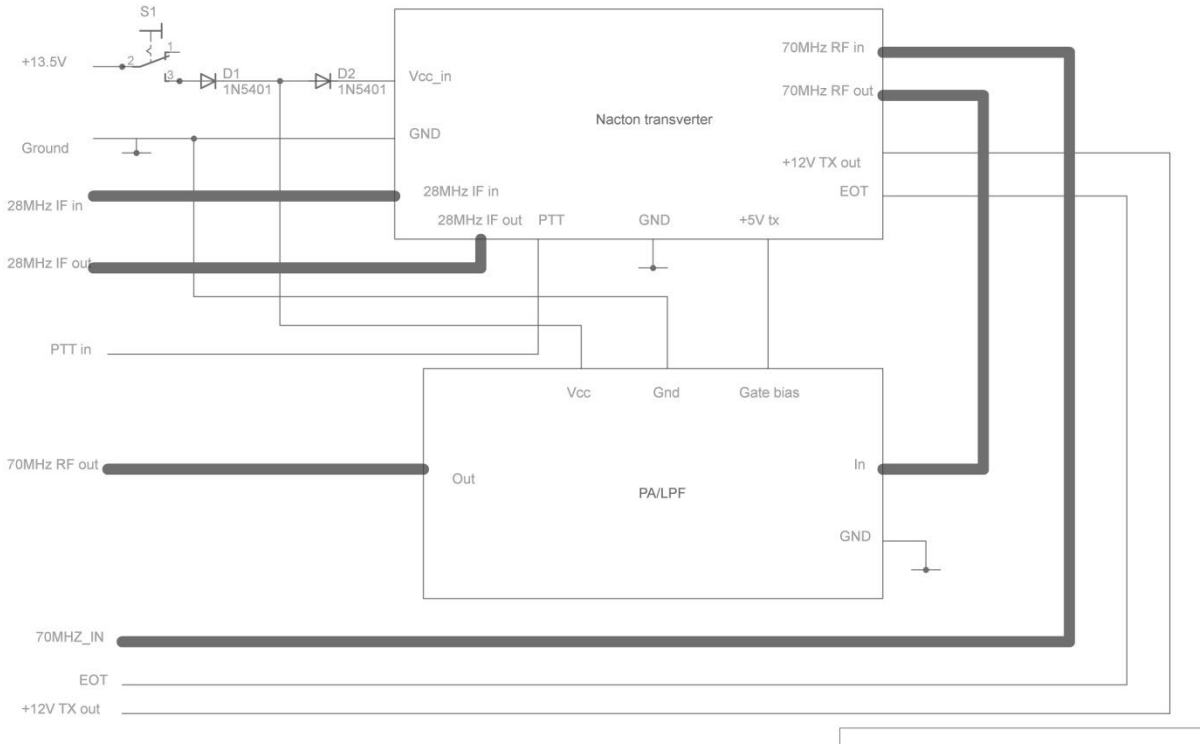


Fig3. wiring interconnections for the Nacton transverter module and the PA/LPF module.

PCBs for the PA/LPF

PCBs for the PA/LPF can be purchased from G4DDK. Please contact me at sam@g4ddk.com for details of price and availability

Document history

Date	Issue	Changes
24/3/14	V0.1	Initial document